SOME CALCULATIONS OF NEUTRON CAPTURE CROSS-SECTIONS

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ABSTRACT.. Neutron capture cross-sections were calculated for about 30 cases at 24 keV, using low energy resonance parameters. These cross-sections were compared with previously measured values of the cross-sections. In most of the cases, except neutron magic number nuclei a good agreement was found between the experimental and the theoretical values.

INTRODUCTION

We have measured (Chaubey and Sehgal 1965 and 1966) capture cross-sections at 24 keV for about 50 nuclei, using antimony-beryllium photoneutron sources. Cross-sections in the keV energy region are helpful in the design of the reactors and in the study of the cosmological theories of element formation (Burbidge *et al* 1957) as well as in the study of nuclear reaction theories (Margolis 1952), (Feschbach *et al* 1954), (Mossion-Kotin *et al* 1959). Cross-section values at low energies are very useful for testing various nuclear models.

In the present work we have calculated the capture cross-sections at 24 keV for about 20 cases. For 10 case results have been published earlier (Chaubey and Sehgal 1965). Thus in all, for 30 cases, cross-sections calculated by the method of Booth *et al* (1958) were compared with our previously measured (Chaubey and Sehgal 1965, 1966) cross-section values (σ expt). In this way the theoretical formula (Booth *et al* 1958) of capture cross-section and hence the theory on which this formula is based was checked at 24 keV.

CALCULATIONS OF CAPTURE CROSS-SECTIONS

We have calculated the capture cross-sections at 24 keV, following the method of Booth *et al* (1958). The following relation is used for the calculations of the cross-sections :

$$\sigma_a = \sum_J \frac{2J+1}{2(2I+1)} \tfrac{1}{2}\pi \left(\frac{2.6\times 10^6}{E_n}\right)\frac{\Gamma_r}{D}$$

$$\times\left[1-(b\pi)^{\frac{1}{2}}\left\{1-\frac{2}{\sqrt{\pi}}\int_0^{\sqrt{b}} \exp(-t^2)dt\right\}\right] \quad \ldots \quad (1)$$

where $b = \Gamma_r/(2V_0\Gamma_n{}^0)$,

and I is the spin of the target nucleus, J is the total angular momentum of the compound nucleus, E_n is the energy of the nutrons expressed in eV and V_0 is the pene: tration factor (taken equal to unity for zero angular momentum). The quantities Γ_r, D and $\Gamma_n{}^0$ are experimentally easured (BNL-325, IInd ed., 1958 and its supplement no. 1 (1960) and Levin and Hughes 1956), radiation width level spacing and reduced neutron width respectively. The value of these parameters were taken as the average over all the s-wave reasonances. While calculating the capture cross-section from this formula it was assumed (Booth *et al* 1958) that only s-wave neutron contribute to the cross-section and the contribution due to p-wave neutron is almost zero. It was also assumed that the low energy resonance parameters can be used at 24 keV.

In most of the cases values of the resonance parameters were taken from BNL-325, (1958, 1960). While calculating the value of level sacing from these references the average level spacing for zero spin target nuclei was taken to be equal to the observed level spacing whereas for nonzero spin target nuclei, the average level spacing is taken to be twice that of the observed level spacing (Carter *et al* 1954).

The values of the capture cross-sections experimentally measured (σ_{expt}) and theoretically calculated (σ_{theo}) are shown in table 1. For Mn^{55}, Ag^{107}, Cd^{114}, In^{115}, Te^{126}, Dy^{164}, Ho^{165}, Lu^{175}, Au^{107} and Th^{232}. The results have been taken from our previous paper (Chaubey and Sehgal, 1965). In Zn^{68}, Se^{80}, Br^{79}, Rh^{103}, Pd^{108}, In^{115} and Dy^{164} (Chaubey and Sehgal, 1965, 1966) values of σ_{expt} are the sum of the cross-sections for the isomeric and the ground states and thus are total capture cross-section. The calculated cross-section in all the above cases is also the total capture cross-section. We find that except in the case of Zn^{68} and Pd^{108} there is a reasonable agreement between σ_{expt} and σ_{theo}. In Pd^{110} and In^{113} values of σ_{expt} are only for the ground state as the cross-section for the isomeric state is not known, therefore it is not desirable to make any comparison between σ_{expt} and σ_{theo}.

In figure 1 the ratio $\sigma_{expt}/\sigma_{theo}$ has been plotted versus the number of neutrons in the target nucleus. It is clear from this figure that in most of the cases the points lie around the line corresponding to the ratio 1. In general the agreement in the experimental and theoretical values of the cross-sections is good. It is interesting to note that in the above calculations of the cross-sections only the

Table 1. Table shows a comparison in the experimentally measured and theoretically calculated capture cross-sections

Target nucleus	σ_{expt} (mb)	σ_{theo} (mb)	Reference for Γ_r and D
Mn^{55}	40 ± 3	35	a
Zn^{68}	27 ± 3	1.6	a
Ga^{69}	50 ± 5	126.4	a
Ga^{71}	75 ± 10	122	a
Se^{80}	13 ± 1.8	14.7	a
Br^{79}	624 ± 46	672	a
Br^{81}	560 ± 100	350	c
Rh^{103}	510 ± 51	510	a
Pd^{108}	185 ± 15	524	a
Pd^{110}	120 ± 15	2034	a
Ag^{107}	810 ± 90	952	a
Ag^{109}	609 ± 60	647	b
Cd^{114}	240 ± 25	163	a
In^{113}	260 ± 100	1046	b
In^{115}	800 ± 60	813	c
Te^{126}	66 ± 11	65.5	a
Ba^{138}	7 ± 1.4	0.5	a
La^{139}	50 ± 10	173	b
Pr^{141}	100 ± 15	49	a
Dy^{164}	190 ± 20	203.5	a
Ho^{165}	990 ± 70	935	a
Lu^{175}	1670 ± 120	1700	a
W^{186}	155 ± 20	64	a
Re^{185}	1765 ± 265	1976	b
Re^{187}	875 ± 80	637	a
Ir^{193}	630 ± 50	5230	b
Pt^{198}	205 ± 30	200	a
Au^{197}	500 ± 35	607	a
Pb^{208}	6.5 ± 1.5	0.67	a
Th^{232}	480 ± 50	340	a

a—Supplement no. 1 of BNL-325, 1960 b—BNL-325 II-nd ed., 1958
c—Carter *et al* (1954).

contribution due to *s*-wave neutrons has been taken into account. It is a well known fact that at this energy there will be appreciable contribution due to *p*-wave and *d*-wave neutrons, which, when taken into account will change the value of the theoretically calculated cross-sections giving poor agreement with the experimental values. It may be worthwhile for some theorist to look into this expression of the cross-section for this anamoly.

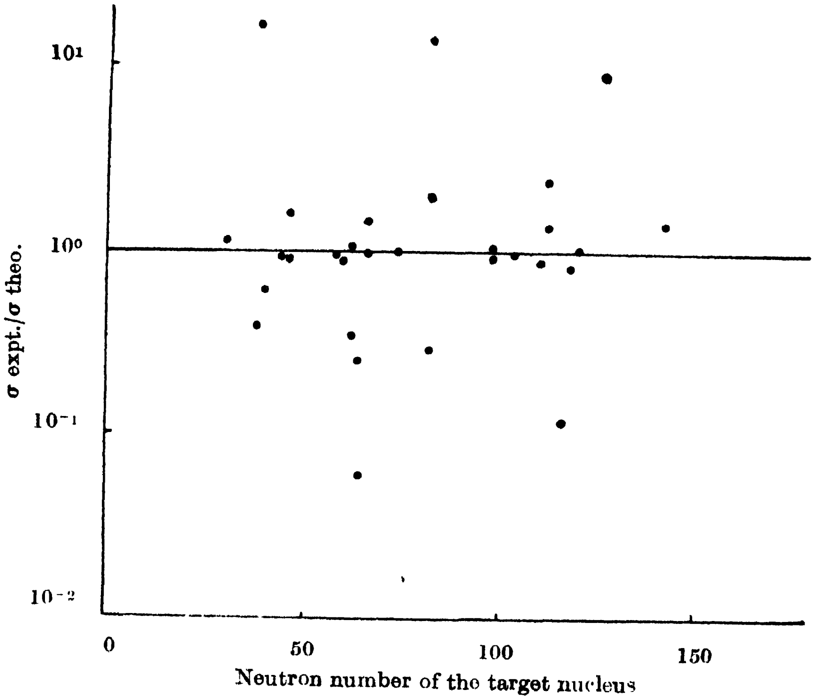

Figure 1. The ratio of experimentally measured and theoretically calculated cross-sections is plotted against the neutron number of the target nucleus. In general the points are scattered about the line having ratio 1.

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